

Icehouse Effect: A Selective Arctic Cooling Trend Current Models are Missing

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Abstract

The icehouse effect is a hypothesized climate feedback mechanism which could result in human-caused surface cooling trends in polar regions. Once understood in detail, it becomes apparent that these trends, which are discernable in the literature, but have been largely dismissed, do not conflict with the consensus assessment of the evidence, which infers century-scale Arctic warming. In fact, confirmation of the hypothesis would substantially strengthen the argument that there is a detectable human influence on today's climate. This apparent enigma is resolved only through careful attention to the detail of the hypothesis and the data supporting it. The posited surface cooling is entirely dependent on the existence of climate warming in layers capping the stable boundary layer. Also, the cooling is not pandemic, but is selective. It is readily revealed in properly sorted data, by making use of the principles of micrometeorological similarity. Specifically, the cooling is manifest under a range of favorable turbulence conditions which can develop and disappear locally on time scales of minutes to hours because of the intrinsically intermittent nature of stable boundary layer turbulence. Because of the fine-scale nature of the processes which produce the cooling, modeling it is a difficult proposition. Vertical resolution on the order of 1 meter is required. Adequate models of intermittent surface fluxes coupled with radiation exchange do not currently exist, not as parameterizations for aggregated systems, nor in large eddy simulation (LES) models. This presentation will introduce the theory. An important testable null hypothesis emerges: the icehouse effect produces a unique signature or "fingerprint" which could not be produced by any other known process. The presence of this signature will be demonstrated using nearly all available Arctic temperature observations. Its aggregate effect is clearly found in Arctic monthly surface temperature trends when sorted by climatological stability. Using all available Arctic rawinsonde ascents – about 1.1 million profiles, "frozen moments" of the icehouse processes are captured in various stages. Because turbulent time scales are so short in the stable boundary layer, each of these snapshots can be treated as independent -- their chronology is irrelevant. Micrometeorological similarity is invoked to reassemble the soundings into bins of similar stability, and it is in a wide, coherent range of these stability bins where the cooling effect is revealed.

1 Introduction: A mechanism for surface cooling

Climate trends for surface temperature are normally evaluated using two extreme readings per day – the maximum and the minimum. One can envision a fictitious scenario where two stations with identical maximum-minimum climatology have very different continuous-mean temperatures. Similarly, January and July temperatures are often given disproportionate focus in climate analyses. This paper proposes that there is a significant surface temperature trend in polar regions which opposes the trend of the extremes, which is manifest in the intermediate temperatures between both diurnal and seasonal extremes. Specifically, there is a cooling trend which is occurring selectively during periods when the boundary layer is stably stratified, and undergoing radiational cooling and turbulent dissipation (evening, autumn). This cooling is a negative feedback response which is very sensitive to any intrusion of warm, lower

density air from lower latitudes. Warm air is forced to decouple from the surface as it moves over colder, denser air in place over the polar ice. If warm intrusions are increasing in frequency and/or duration, and/or are shallower (closer to the surface) or of greater intensity (warmer), due to greenhouse effects or circulation changes, then the cooling response will also increase with time.

As a brief tutorial, the stable boundary layer is defined as all air layers linked to the surface by intermittent or continuous turbulence, which, if moved vertically, will tend to return to their original level. In the absence of sunlight, the stable boundary layer generally cools, driven by surface radiational heat loss. The cooling is modulated by any turbulence, which mixes the surface cooling vertically, exchanging the cooler surface air with warmer air aloft. The intensity of turbulence is inversely proportional to the rate of increase of temperature with height. The rate of dissipation of any existing turbulence is directly proportional to the same. The greater the increase of temperature with height, the more stability the boundary layer is said to have.

Given these simple facts, it is straightforward to describe an idealized (assumed fictitious for now) sequence of events which would lead to a polar cooling trend in the presence of greenhouse warming elsewhere. Greenhouse warmed air is transported poleward and crosses a region in which the surface is composed of an ice-water mix. Since the temperature at which water freezes is independent of greenhouse effects, a layer of $\sim 0^{\circ}\text{C}$ air is formed at the surface. Overlying it, the air is assumed warmer than 0°C , so the boundary layer is stably stratified. In analogy to the icehouse of old, the polar ice effectively preserves itself, the stable air layer established above it provides the icehouse "walls", preventing warm air from invading horizontally, and the inversion created as the warm air is lifted over the stable layer provides the "roof". When the "roof" is lower or thicker (i.e. the inversion is stronger), there is less air for the ice and snow to keep chilled, and so the icehouse is more efficient.

Let us now envision two parallel poleward-moving airmasses, one with greenhouse warming and one without. The air above the surface will be warmer in the greenhouse airmass, so the boundary layer will be more stably stratified in this case. The result is a lower, stronger icehouse "roof": there will be less turbulence in a shallower layer than in the non-greenhouse airmass. The two airmasses continue poleward and encounter snow cover (an excellent insulator), which is emitting radiation to space faster than turbulence is bringing more warm air from aloft down to make contact with the surface. In the absence of sunlight or heat conduction from below through the snow, the surface energy balance is negative and the surface-air interface is therefore cooling below 0°C . Because of the comparative absence of turbulence in the greenhouse airmass, there is a weaker downward flux of heat from the air, so the surface is able to cool faster, and will become colder.

It is straightforward to show that the difference in turbulent transport of heat down to the surface between the greenhouse warmed airmass and the non-greenhouse airmass can be much larger than the difference in radiational heat flux caused by, say, a doubling of carbon dioxide content in the greenhouse airmass. Therefore the direct radiative effects of greenhouse warming can be readily overwhelmed by the turbulent boundary layer processes under this special set of circumstances. Furthermore, it can be easily shown that this difference between the cooling effect due to decreased turbulence and the direct warming due to greenhouse gases is largest for a selective range of stability.

For unstable and weakly stable conditions, turbulence mixes air deeply and vigorously, so the difference in turbulent transport between the greenhouse and non-greenhouse airmasses is a minor effect under these conditions. On the other end of the stability spectrum, for very stable air masses, turbulence is so strongly suppressed in both airmasses that there is again little resulting effect on the difference in turbulent transport. It is in the intermediate range of stabilities, where the hypothesized cooling effect is to be expected.

To reiterate, there is a stability dependence of the hypothesized process. If one sorts observations by stability, one would expect to find greenhouse warming trends at both extremes of stability. Any cooling trend will manifest itself in the center of the stability range. This stability dependence would not exist if some other process were causing the observed temperature trends. Therefore, if a cooling trend is found

only in the central range of stabilities in observed polar surface temperatures, this could be taken as significant evidence that the hypothesized icehouse effect is the causal process.

In the next section we examine all the available data, sorted by stability – an analysis which has not been done by others. The data are in the public domain, so analyses such as are presented here, are readily reproducible by others.

2 A look at all the Arctic surface temperature and balloon data

Figure 1 presents the analysis of virtually all available Arctic balloon soundings, 1.1 million of them, at all stations north of 65°N, available from the National Snow and Ice Data Center (NSIDC). In order to assure consistency between different observational protocols, the stability measure uses the surface temperature and the standard level of 850hPa. The latter is always well above the boundary layer, so the stability classification is likely to be degraded by the lack of better vertical resolution. If there is a trend in stability in the observations, its effect is negligible compared to the range of stability depicted. Trends toward greater stability (a shift of the frequency distribution toward the right of the figures) would be expected based on the proposed hypothesis. The data are divided into the Russian stations, which have a period of record encompassing only the recent era of rapid global warming, (yet selective cooling still appears), and the rest of the Arctic, for which balloon data are available back to 1948 for many stations. The results clearly show the stability dependent signature of the hypothesized icehouse effect: climate warming at the wings of the stability spectrum, with a cooling (or relative lack of warming) in the central stability range.

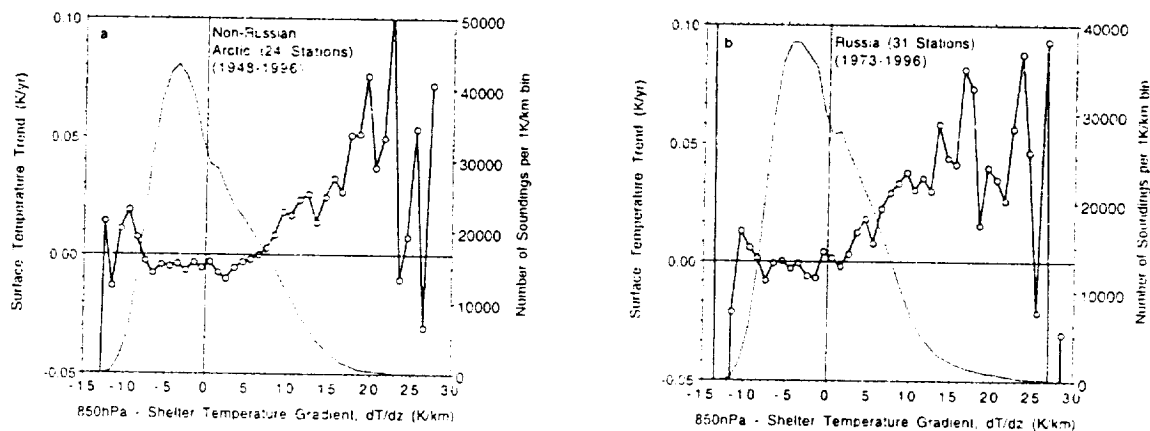


Figure 1: Surface temperature trends (open circles keyed to left scale) from Arctic rawinsonde data sorted by stability (represented by the surface to 850hpa temperature gradient). Note the unique signature: a cooling trend only in the central range of stability, as hypothesized.

In Figure 2, monthly mean surface temperature data for the entire period of record of 66 stations north of the Arctic Circle are analyzed. Data are available on the internet from the Lamont-Doherty Earth Observatory (LDEO). Monthly temperatures could only show an aggregate effect of the short term, micro-scale process which produces icehouse cooling. It is indeed surprising, and an apparent strong confirmation of the pervasive effect of the hypothesized processes, that the unique stability dependent signature is apparent in monthly data.

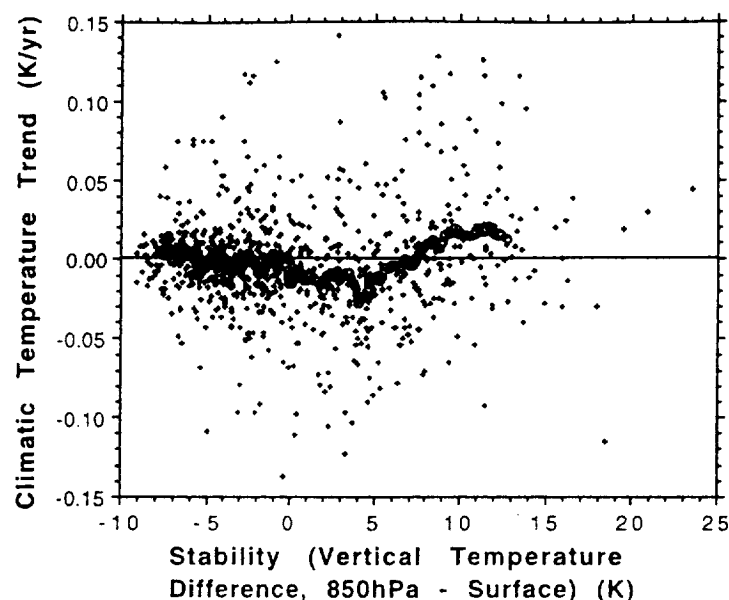


Figure 2. Same as Figure 1 except for monthly surface temperature data from 66 stations north of the Arctic circle. Period of record for some stations exceeds 90 years. Each small "+" symbol represents the period-of-record trend for a single month at one station. Open circles are a 51 point running average. 850hPa climatology for the month is used to estimate the stability only crudely, yet a cooling trend still clearly appears in the central range of stability in the smoothed data.

3 Discussion

Clearly this short presentation leaves many open questions. There is an enormous gap between cause and effect which one must bridge in order to connect the hypothesized scenario presented in section 1 with the observations presented in Section 2. High resolution boundary layer modeling in one, two and three dimensions holds the best promise of bridging this gap. Since, as discussed in the abstract, adequate models of stable boundary layer turbulence and radiation have yet to be developed (even conceptually), there is a long road to travel before this work is complete. This author has performed preliminary, pathfinding modeling which confirms cause and effect, and reproduces the observed icehouse signature under simplified but realistic assumptions. These results have been reported previously [1,2].

The key point the reader should extract from this presentation is that the observational data show a peculiar and unique stability dependence in the long term surface temperature trends, which is explained by the icehouse hypothesis, and would not be explained if other processes dominated the surface temperature trends.

References

- [1] P. J. Wetzel, "The icehouse hypothesis," *Proceedings, ACSYS Conference on Polar Processes and Global Climate*, 3-7 Nov., Orcas Island, Washington, USA, 293-295, (1997).
- [2] P. J. Wetzel, "Icehouse effect: A polar autumn and winter cooling trend?" *Preprints, Tenth Symposium on Global Change Studies, American Meteorological Soc.*, 10-15 Jan., Dallas, Texas, USA, 273-276, (1999).